

# **SENSORS AND SENSOR NETWORKS**

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## **Program Solicitation**

**NSF 03-512**



### **National Science Foundation**

Directorate for Engineering

Division of Bioengineering and Environmental Systems

Division of Civil and Mechanical Systems

Division of Chemical and Transport Systems

Division of Design, Manufacture, and Industrial Innovation

Division of Electrical and Communications Systems

Directorate for Computer and Information Science and Engineering

Division of Advanced Computational Infrastructure and Research

Division of Advanced Networking Infrastructure and Research

Division of Computer-Communications Research

Division of Experimental and Integrative Activities

Division of Information and Intelligent Systems

**Full Proposal Deadline(s)** (due by 5 p.m proposer's local time):

March 06, 2003

## **SUMMARY OF PROGRAM REQUIREMENTS**

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### **General Information**

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**Program Title:**

SENSORS AND SENSOR NETWORKS

**Synopsis of Program:**

The National Science Foundation (NSF), through the Directorate for Engineering and the Directorate for Computer and Information Science and Engineering, announces a broad interdisciplinary program of research and education in the area of advanced sensor development. This solicitation seeks to advance fundamental knowledge in the areas of

sensor design, materials and concepts, including sensors for toxic chemicals, explosives and biological agents, sensor networking systems in a distributed environment, the integration of sensors into engineered systems, and the interpretation and use of sensor data in decision-making processes. The Directorate for Mathematical and Physical Sciences, the Directorate for Biological Sciences, the Directorate for Geosciences, and the Office of Polar Programs plan to participate in the reviews and identify proposals of mutual interest and may provide co-funding for programs of high quality that meet their programmatic requirements.

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### **Applicable Catalog of Federal Domestic Assistance (CFDA) Number(s):**

- 47.070 --- Computer and Information Science and Engineering
- 47.041 --- Engineering

## Eligibility Information

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- **Organization Limit:**

Proposals may be submitted only by U.S academic institutions and nonprofit research institutions in support of individual investigators, small teams, and larger interdisciplinary research groups.

- **PI Eligibility Limit:**

Only one proposal may be submitted by a Principal Investigator. However, a Principal Investigator for one proposal may be a co-Principal Investigator or research associate on one other proposal. Group and collaborative proposals involving more than one institution must be submitted as a single administrative package from the lead institution.

- **Limit on Number of Proposals:** Only as stated in the PI Eligibility Limit.

## Award Information

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- **Anticipated Type of Award:** Standard or Continuing Grant
- **Estimated Number of Awards:** 55 to 60
- **Anticipated Funding Amount:** \$34,000,000 for Single-Investigator (up to \$125K/yr for 3 years), Small-Team (up to \$250K/yr for 3 years), and Interdisciplinary-Research-Group (up to \$2.5M covering a period up to 5 years) awards, subject to availability of funds and the quality of proposals received.

## Proposal Preparation and Submission Instructions

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### A. Proposal Preparation Instructions

- **Full Proposal Preparation Instructions:** The program announcement/solicitation contains supplements to the standard Grant Proposal Guide (GPG) proposal preparation guidelines. Please see the full program announcement/solicitation for further information.

### B. Budgetary Information

- **Cost Sharing Requirements:** Cost Sharing is not required.
- **Indirect Cost (F&A) Limitations:** Not Applicable.
- **Other Budgetary Limitations:** Not Applicable.

### C. Due Dates

- **Full Proposal Deadline Date(s)** (due by 5 p.m proposer's local time):  
March 06, 2003

## Proposal Review Information

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- **Merit Review Criteria:** National Science Board approved criteria apply.

## Award Administration Information

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- **Award Conditions:** Standard NSF award conditions apply.
- **Reporting Requirements:** Standard NSF reporting requirements apply.

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## I. INTRODUCTION

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In recent years, sensor research has been undergoing a quiet revolution, promising to have significant impact on a broad range of applications relating to national security, health care, the environment, energy, food safety, and manufacturing. The convergence of the Internet, communications, and information technologies with techniques for miniaturization has placed sensor technology at the threshold of a period of major growth. Emerging technologies can decrease the size, weight and cost of sensors and sensor arrays by orders of magnitude, and increase their spatial and temporal resolution and accuracy. Large numbers of sensors may be integrated into systems to improve performance and lifetime, and decrease life-cycle costs. Communications networks provide rapid access to information and computing, eliminating the barriers of distance and time for telemedicine, transportation, tracking endangered species, detecting toxic agents, and monitoring the security of civil and engineering infrastructures. The coming years will likely see a growing reliance on and need for more powerful sensor systems, with increased performance and functionality.

Some needs for new sensors and sensor systems include (1) the ability to respond to new toxic chemicals, explosives and biological agents, (2) enhanced sensitivity, selectivity, speed, robustness, and fewer false alarms, and (3) the ability to function, perhaps autonomously, in unusual/extreme/complex environments. These needs can be addressed by the design and synthesis of functionalized receptors and materials resulting in next-generation devices. The materials may be of varying porosity enabling them to detect single toxic compounds in complex mixtures, or physical configurations that have surfaces with microchannels for microfluidic discrimination. The full battery of advanced biological, chemical and materials research can be brought to bear on this challenge, including the design of functional nano- and meso-scale complex structures (e.g., quantum dots, nanowires, gels). Robustness under anticipated manufacturing schemes is required. Sensor arrays are of interest in this regard. Quantification of sensor data including limits of detection, calibration, interferences, sampling and verification of accuracy also needs to be considered.

Miniaturization, manufacture and cost are also issues. Integration of sensors, processors, energy sources, and the communications network interface on a chip would facilitate the exchange of sensor data and critical information with the outside world. Information extraction may involve detection of events or objects of interest, estimation of key parameters, and human-in-the-loop or closed-loop adaptive feedback. Arrays of ultra low-power wireless nodes may be incorporated in reconfigurable networks with high-speed connectivity to processing centers for decision and responsive action.

Sensing principles include but are not limited to mechanical, chemical, thermal, electrical, chromatographic, magnetic, biological, fluidic, optical, ultrasonic and mass sensing. Sensors may be exposed to hostile environments. They may be incorporated in mobile robotic systems, or integral to manufacturing systems. Their environment may include high temperatures, high vibration, high noise, or corrosive chemicals. In biological systems, the sensors themselves must not adversely affect the system or organism. The technology for sensing and control now has the potential for significant advances, with profound benefits for society.

To meet future societal needs, it will be necessary for sensor systems to leverage and incorporate projected advances in adjacent technologies, such as nanofabrication, biosystems, massively distributed networks, ubiquitous computing, broadband wireless communications, and information and decision systems.

Successful invention of low-cost, robust, miniaturized sensors and detection equipment such as mass spectrometers and chromatographs will be of benefit to the scientific education community. Education projects about sensors have the potential to attract students to a fruitful interdisciplinary area with clear societal benefits. The area has the potential to help build a diverse scientific workforce.

Recent NSF workshop reports at <http://www.chemistry.gatech.edu/sensingforum-02> and <http://www.ce.berkeley.edu/Programs/Geoengineering/sensors> discuss projected sensor needs.

## II. PROGRAM DESCRIPTION

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This multidisciplinary research activity seeks to advance fundamental knowledge in new sensor technologies, including sensors for toxic chemicals, explosives and biological agents, sensor networking systems in a distributed environment, the integration of sensors into engineered systems, and the interpretation and use of sensor data in decision-making processes. It is envisioned that research will be carried out by individual investigators, as well as by small teams and larger interdisciplinary groups that generate new concepts and approaches stimulated by the synergistic interaction of diverse disciplines. Proposals providing new sensing principles and/or materials, built-in sensor intelligence, improved performance and security, and high data-rate management capabilities are particularly encouraged. It is important that the research programs on advanced sensing concepts identify and address target applications, and projects should show a clear relationship to the requirements of the application. The community is encouraged to be innovative in educational aspects of sensor research. Projects should include underrepresented groups through the research and outreach.

### TOPICAL AREAS

This solicitation will provide research support under three topical areas as follows. It is intended that these areas be broadly defined. Examples are provided to explore the breadth of each topic and are not intended to be all-inclusive.

#### *Designs, Materials and Concepts for New Sensors and Sensing Systems*

Examples include: novel sensing materials and devices; the design of solid and liquid surfaces with molecular recognition, long lifetime, and regenerability of the sensing site; biomimetic sensors including hybrids consisting of proteins, enzyme fragments/components, bio-organometallics or other biocatalysts that can be linked to surfaces; bioMEMS; sensors for toxic agents (biological, chemical, radiation); sensors for operation in harsh environments; wireless sensors; chip-based systems incorporating multiple sensors, computation, actuation, and wireless interfaces; sensor systems capable of remote activation and interrogation; sensor power sources; novel optical imaging concepts; novel techniques for metrology at the nanoscale; new modeling and simulation tools; new techniques for on-sensor self-calibration and self-test; enhanced specificity to maximize accuracy and minimize false alarms; and new methods for sensor fabrication, manufacture and encapsulation.

## *Arrayed Sensor Networks and Networking*

This area includes: enabling networking technologies for distributed wireless and wired sensor networks; scalable and robust architectures; design, automated tasking, and querying techniques; adaptive management and control of sensor nodes; design tradeoffs and performance optimization in resource-constrained sensor networks; design of ultra-low power processing nodes for local information management; investigation of localized versus distributed versus centralized processing of sensor data; common building blocks and interfaces for sensor networking; strategies for using heterogeneous sensor and network nodes to enhance performance and reduce false alarms; security and authentication for resource-constrained sensor networks; embedded and hybrid systems; application-specific network and system services, including data-centric routing, attribute-based addressing, location management and service discovery; energy-efficient media access, error control and traffic management protocols; mobile sensor networks; scalable reconfigurability and self-organization.

## *Interpretation, Decision and Action Based on Sensor Data*

Examples include: decision theory for intelligent use of sensed information; detection and identification of false alarms; feedback theory; development of new statistical algorithms, sampling theories and supervisory control systems tailored to needs; concepts for optimal sensor locations for effective process/system control; mathematical hybrid system tools for monitoring distributed networks of large arrays of sensors and actuators; hand-held diagnostic kits; and pattern recognition and state estimation. System-level sensor applications include: biomedical health monitoring, diagnostic, and therapeutic systems; image-guided surgery; health monitoring systems for civil structures; crisis management sensor systems; surveillance technology; robotics; mobile sensors; tracking/monitoring of mobile units (endangered species, inventory control, transportation); and sensor assessment (reliability, verification, validation).

## **III. ELIGIBILITY INFORMATION**

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Proposals may only be submitted by U.S. academic institutions and nonprofit research institutions in support of individual investigators, small teams, and larger interdisciplinary research groups. For other information, the [Grant Proposal Guide](#) should be consulted.

## **IV. AWARD INFORMATION**

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- **Anticipated Type of Award:** Standard or Continuing Grant
- **Estimated Number of Awards:** 55 to 60
- **Anticipated Funding Amount:** \$34,000,000 for awards of the following types:
  - Single-Investigator Awards (up to \$125K/yr for 3 years),
  - Small-Team Awards (up to \$250K/yr for 3 years), and
  - Interdisciplinary-Research-Group Awards (up to \$2.5M covering a period up to 5 years).

Estimated program budget, number of awards, and average award size/duration are subject to the availability of funds and quality of proposals received.

## **V. PROPOSAL PREPARATION AND SUBMISSION INSTRUCTIONS**

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### **A. Proposal Preparation Instructions**

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#### **Full Proposal Instructions:**

Proposals submitted in response to this program announcement/solicitation should be prepared and submitted in accordance with the general guidelines contained in the NSF *Grant Proposal Guide* (GPG). The complete text of the GPG is available electronically on the NSF Website at: <http://www.nsf.gov/cgi-bin/getpub?gpg>. Paper copies of the GPG may be obtained from the NSF Publications

Clearinghouse, telephone (301) 947-2722 or by e-mail from [pubs@nsf.gov](mailto:pubs@nsf.gov).

The program solicitation contains supplements to the Grant Proposal Guide (GPG) proposal preparation guidelines. Please see full program solicitation for further information.

Cover Sheet: See GPG Section II.C.

- Project Title. The project title must begin with "SENSORS:" and follow with an informative title.

- Program selection. In order to facilitate proper assignment and review of proposals, **individual-investigator proposals must identify the disciplinary program** closest to the subject matter of the proposed activities. **For all small-team and group interdisciplinary proposals, applicants must select "ECS - Integrative Systems" as the division-program of interest.** Failure to do so may cause delays in processing.

Project Description: See GPG Section II.C.

- Note: the project description may not exceed 15 pages for any proposal submitted in response to this solicitation.

Proposers are reminded to identify the program announcement/solicitation number ((03-512)) in the program announcement/solicitation block on the proposal Cover Sheet. Compliance with this requirement is critical to determining the relevant proposal processing guidelines. Failure to submit this information may delay processing.

## **B. Budgetary Information**

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### **Cost Sharing:**

Cost sharing is not required in proposals submitted under this Program Solicitation.

## **C. Due Dates**

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Proposals must be submitted by the following date(s):

**Full Proposal Deadline(s)** (due by 5 p.m proposer's local time):

March 06, 2003

## **D. FastLane Requirements**

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Proposers are required to prepare and submit all proposals for this announcement/solicitation through the FastLane system. Detailed instructions for proposal preparation and submission via FastLane are available at: <http://www.fastlane.nsf.gov/a1/newstan.htm>. For FastLane user support, call the FastLane Help Desk at 1-800-673-6188 or e-mail [fastlane@nsf.gov](mailto:fastlane@nsf.gov). The FastLane Help Desk answers general technical questions related to the use of the FastLane system. Specific questions related to this program announcement/solicitation should be referred to the NSF program staff contact(s) listed in Section VIII of this announcement/solicitation.

*Submission of Electronically Signed Cover Sheets.* The Authorized Organizational Representative (AOR) must electronically sign the proposal Cover Sheet to submit the required proposal certifications (see Chapter II, Section C of the [Grant Proposal Guide](#) for a listing of the certifications). The AOR must provide the required electronic certifications within five working days following the electronic submission of the proposal. Proposers are no longer required to provide a paper copy of the signed Proposal Cover Sheet to NSF.

Further instructions regarding this process are available on the FastLane Website at: <http://www.fastlane.nsf.gov>

## **VI. PROPOSAL REVIEW INFORMATION**

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### **A. NSF Proposal Review Process**

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Reviews of proposals submitted to NSF are solicited from peers with expertise in the substantive area of the proposed research or education project. These reviewers are selected by Program Officers charged with the oversight of the review process. NSF invites the proposer to suggest, at the time of submission, the names of appropriate or inappropriate reviewers. Care is taken to ensure that reviewers have no conflicts with the proposer. Special efforts are made to recruit reviewers from non-academic institutions, minority-serving institutions, or adjacent disciplines to that principally addressed in the proposal.

The National Science Board approved revised criteria for evaluating proposals at its meeting on March 28, 1997 ([NSB 97-72](#)). All NSF proposals are evaluated through use of the two merit review criteria. In some instances, however, NSF will employ additional criteria as required to highlight the specific objectives of certain programs and activities.

On July 8, 2002, the NSF Director issued Important Notice 127, Implementation of new Grant Proposal Guide Requirements Related to the Broader Impacts Criterion. This Important Notice reinforces the importance of addressing both criteria in the preparation and review of all proposals submitted to NSF. NSF continues to strengthen its internal processes to ensure that both of the merit review criteria are addressed when making funding decisions.

In an effort to increase compliance with these requirements, the January 2002 issuance of the GPG incorporated revised proposal preparation guidelines relating to the development of the Project Summary and Project Description. Chapter II of the GPG specifies that Principal Investigators (PIs) must address both merit review criteria in separate statements within the one-page Project Summary. This chapter also reiterates that broader impacts resulting from the proposed project must be addressed in the Project Description and described as an integral part of the narrative.

Effective October 1, 2002, NSF will return without review proposals that do not separately address both merit review criteria within the Project Summary. It is believed that these changes to NSF proposal preparation and processing guidelines will more clearly articulate the importance of broader impacts to NSF-funded projects.

The two National Science Board approved merit review criteria are listed below (see the [Grant Proposal Guide](#) Chapter III.A for further information). The criteria include considerations that help define them. These considerations are suggestions and not all will apply to any given proposal. While proposers must address both merit review criteria, reviewers will be asked to address only those considerations that are relevant to the proposal being considered and for which he/she is qualified to make judgements.

#### **What is the intellectual merit of the proposed activity?**

How important is the proposed activity to advancing knowledge and understanding within its own field or across different fields? How well qualified is the proposer (individual or team) to conduct the project? (If appropriate, the reviewer will comment on the quality of the prior work.) To what extent does the proposed activity suggest and explore creative and original concepts? How well conceived and organized is the proposed activity? Is there sufficient access to resources?

#### **What are the broader impacts of the proposed activity?**

How well does the activity advance discovery and understanding while promoting teaching, training, and learning? How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc.)? To what extent will it enhance the infrastructure for research and education, such as facilities, instrumentation, networks, and partnerships? Will the results be disseminated broadly to enhance scientific and technological understanding? What may be the benefits of the proposed activity to society?

NSF staff will give careful consideration to the following in making funding decisions:

#### ***Integration of Research and Education***



One of the principal strategies in support of NSF's goals is to foster integration of research and education through the programs, projects, and activities it supports at academic and research institutions. These institutions provide abundant opportunities where individuals may concurrently assume responsibilities as researchers, educators, and students and where all can engage in joint efforts that infuse education with the excitement of discovery and enrich research through the diversity of learning perspectives.

### ***Integrating Diversity into NSF Programs, Projects, and Activities***

Broadening opportunities and enabling the participation of all citizens -- women and men, underrepresented minorities, and persons with disabilities -- is essential to the health and vitality of science and engineering. NSF is committed to this principle of diversity and deems it central to the programs, projects, and activities it considers and supports.

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## **B. Review Protocol and Associated Customer Service Standard**

All proposals are carefully reviewed by at least three other persons outside NSF who are experts in the particular field represented by the proposal. Proposals submitted in response to this announcement/solicitation will be reviewed by Ad Hoc and/or panel review.

Reviewers will be asked to formulate a recommendation to either support or decline each proposal. The Program Officer assigned to manage the proposal's review will consider the advice of reviewers and will formulate a recommendation.

A summary rating and accompanying narrative will be completed and submitted by each reviewer. In all cases, reviews are treated as confidential documents. Verbatim copies of reviews, excluding the names of the reviewers, are sent to the Principal Investigator/Project Director by the Program Director. In addition, the proposer will receive an explanation of the decision to award or decline funding.

NSF is striving to be able to tell applicants whether their proposals have been declined or recommended for funding within six months. The time interval begins on the date of receipt. The interval ends when the Division Director accepts the Program Officer's recommendation.

In all cases, after programmatic approval has been obtained, the proposals recommended for funding will be forwarded to the Division of Grants and Agreements for review of business, financial, and policy implications and the processing and issuance of a grant or other agreement. Proposers are cautioned that only a Grants and Agreements Officer may make commitments, obligations or awards on behalf of NSF or authorize the expenditure of funds. No commitment on the part of NSF should be inferred from technical or budgetary discussions with a NSF Program Officer. A Principal Investigator or organization that makes financial or personnel commitments in the absence of a grant or cooperative agreement signed by the NSF Grants and Agreements Officer does so at their own risk.

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## **VII. AWARD ADMINISTRATION INFORMATION**

### **A. Notification of the Award**

Notification of the award is made to *the submitting organization* by a Grants Officer in the Division of Grants and Agreements. Organizations whose proposals are declined will be advised as promptly as possible by the cognizant NSF Program Division administering the program. Verbatim copies of reviews, not including the identity of the reviewer, will be provided automatically to the Principal Investigator. (See section VI.A. for additional information on the review process.)

### **B. Award Conditions**

An NSF award consists of: (1) the award letter, which includes any special provisions applicable to the award and any numbered amendments thereto; (2) the budget, which indicates the amounts, by categories of expense, on which NSF has based its support (or otherwise communicates any specific approvals or disapprovals of proposed expenditures); (3) the proposal referenced in the award letter; (4) the applicable award conditions, such as Grant General Conditions (NSF-GC-1); \* or Federal Demonstration Partnership (FDP) Terms and Conditions \* and (5) any announcement or other NSF issuance that may be incorporated by reference in the award

letter. Cooperative agreement awards also are administered in accordance with NSF Cooperative Agreement Terms and Conditions (CA-1). Electronic mail notification is the preferred way to transmit NSF awards to organizations that have electronic mail capabilities and have requested such notification from the Division of Grants and Agreements.

\*These documents may be accessed electronically on NSF's Website at [http://www.nsf.gov/home/grants/grants\\_gac.htm](http://www.nsf.gov/home/grants/grants_gac.htm). Paper copies may be obtained from the NSF Publications Clearinghouse, telephone (301) 947-2722 or by e-mail from [pubs@nsf.gov](mailto:pubs@nsf.gov).

More comprehensive information on NSF Award Conditions is contained in the NSF *Grant Policy Manual* (GPM) Chapter II, available electronically on the NSF Website at <http://www.nsf.gov/cgi-bin/getpub?gpm>. The GPM is also for sale through the Superintendent of Documents, Government Printing Office (GPO), Washington, DC 20402. The telephone number at GPO for subscription information is (202) 512-1800. The GPM may be ordered through the GPO Website at <http://www.gpo.gov>.

### **C. Reporting Requirements**

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For all multi-year grants (including both standard and continuing grants), the PI must submit an annual project report to the cognizant Program Officer at least 90 days before the end of the current budget period.

Within 90 days after the expiration of an award, the PI also is required to submit a final project report. Failure to provide final technical reports delays NSF review and processing of pending proposals for the PI and all Co-PIs. PIs should examine the formats of the required reports in advance to assure availability of required data.

PIs are required to use NSF's electronic project reporting system, available through FastLane, for preparation and submission of annual and final project reports. This system permits electronic submission and updating of project reports, including information on project participants (individual and organizational), activities and findings, publications, and other specific products and contributions. PIs will not be required to re-enter information previously provided, either with a proposal or in earlier updates using the electronic system.

### **VIII. CONTACTS FOR ADDITIONAL INFORMATION**

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General inquiries regarding this program should be made to:

- Filbert J. Bartoli, Program Director, Directorate for Engineering, Division of Electrical & Communications Systems, 675 S, telephone: (703) 292-8339, fax: (703) 292-9147, email: [fbartoli@nsf.gov](mailto:fbartoli@nsf.gov)
- Radhakishan Baheti, Program Director, Directorate for Engineering, Division of Electrical & Communications Systems, 675 S, telephone: (703) 292-8339, fax: (703) 292-9147, email: [rbaheti@nsf.gov](mailto:rbaheti@nsf.gov)
- Mitra Basu, Program Director, Computer & Information Science & Engineering, Experimental and Integrative Activities, 1160N, telephone: (703) 292-8980, fax: (703) 292-9030, email: [mbasu@nsf.gov](mailto:mbasu@nsf.gov)
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For questions related to the use of FastLane, contact:

- FastLane Help Desk, National Science Foundation, telephone: 800-673-6188, email: [fastlane@nsf.gov](mailto:fastlane@nsf.gov)

## **IX. OTHER PROGRAMS OF INTEREST**

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The NSF *Guide to Programs* is a compilation of funding for research and education in science, mathematics, and engineering. The NSF *Guide to Programs* is available electronically at <http://www.nsf.gov/cgi-bin/getpub?gp>. General descriptions of NSF programs, research areas, and eligibility information for proposal submission are provided in each chapter.

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